An Abstract of Mr. BENJAMIN WEST'*s Account of the Transit of Venus, as observed at* Providence, *in New-England, June 3d,* 1769.

As it appears by some letters of the Astronomer Royal, which have been communicated to this Society, that most of the Northern Observers, both in Russia and Sweden, were greatly disappointed, by the unfavourable state of the weather, in their noble and public spirited endeavors to observe the late Transit; the American *Observations have become of the greater importance, in order to a comparison with those of Greenwich, and therefore the Society think it very material to preserve in their Transactions, such of the Observations made on this Continent as they have been favored with. The Account of the* Providence *Observations, drawn up by Mr.* WEST, *was transmitted by Mr.* JOSEPH BROWN, *and being laid before the Society by Dr.* SMITH; *the following Abstract thereof was ordered to be published at a Meeting, May 18th,* 1770.

" WHEN it became more generally known that there would be a Transit of Venus in 1769, and the advantages which were like to accrue to Astro omy, and consequently to Navigation and Chronology, from proper observations of it, Mr. JOSEPH BROWN*, a very respectable merchant of Providence, being very desirous, if possible, to obtain an observation of it, was pleased to advise with me, concerning an apparatus suitable for such an observation, and to know if we should be able to observe the transit with the necessary precision for answering the important design? My answer gave him so much satisfaction in the matter, that he immediately sent his orders to his correspondent in London,

* Reading Mr. Winthrop's account of the transit in 1761, was what first occasioned Mr. BROWN to send for a telescope, fitted in the manner Mr. Winthrop there describes; afterwards, taking notice of the application of the American Philosophical Society to the Assembly of Pennsylvania, for an apparatus for observing the Transit of Venus, he found the orders he had sent were incompleat: He then advised with the author, as mentioned above, and thereupon ordered a micrometer to be added.—Mr. Brown's expence, in this laudable undertaking, was little less than One Hundred Pounds sterling, besides near a month's time of himself and servants, in making the necessary previous experiments and preparations.

don, to procure the inſtruments. His orders were accordingly executed with fidelity and diſpatch; and the inſtruments arrived in Providence about one month before the tranſit. Our apparatus was made by Meſſieurs Watkins and Smith, London; it conſiſted of a three feet reflecting teleſcope, with horizontal and vertical wires for taking differences of altitude and azimuths, adjuſted with ſpirit-levels at right angles, and a divided arch for taking altitudes; a curious helioſcope, together with a micrometer of a new and elegant conſtruction, with rack motions, and fitted to the teleſcope. Beſides the beforementioned inſtruments, we had a ſextant belonging to the government, made in Newport, by Mr Benjamin King, under the direction of Joſeph Harriſon, Eſq; now Collector of his Majeſty's Cuſtoms for the port of Boſton; its limb was divided to five miles, and by a vernier index to five ſeconds§. We had two good clocks, one of which was made in Providence, by Mr. Edward Spalding."

"We had nothing to learn reſpecting the apparatus, excepting our new catadioptric micrometer, which, I have lately learned, is of Dollond's conſtruction; not having any author by us, from which we could get the uſe of that curious inſtrument, we were obliged to have recourſe to experiments. When the micrometer was fixed upon the teleſcope, it was found by trial, that objects could not be ſeen with the ſame focal diſtance as when it was off, and we were obliged to ſcrew up the ſmall ſpeculum nearer to the eye; for which there is an optical reaſon. From whence it was concluded, that objects ſhould always be obſerved in the moſt diſtinct point of view, the ſame with the micrometer on as when it was off. The next thing to be done was to find the apparent diameter of an object (or the angle ſubtended at the eye by two objects) by this inſtrument. In order to this, we ſtretched a cord, as ſtraight as poſſible, one thouſand feet in length; which was meaſured

§ And here we muſt not forget the Hon. Abraham Redwood, Eſq; of Newport, who, in order that Newport and Providence might both be ſupplied with a ſextact, for this ſingular occaſion, ordered one made at his own coſt, for the uſe of the Revd. Dr. Stiles. I am ſenſible Mr. Redwood, for ſo public ſpirited an action, will receive the thanks of every well-wiſher to ſcience.

meaſured ſeveral times over, in order to avoid miſtake. At the end of the cord was ſet two circular objects, made of white paper, in a line perpendicular to the cord, and exactly ten feet apart; ſtanding at the other end of the cord, and by opening the micrometer, we could bring the two images into an exact coincidence, or could make one of the images appear like two, and by bringing their limbs into contact, the diſtance of their centers was ſhewn on the ſcale, to the five hundreth part of an inch. Now from the rules of trigonometry, the angular diſtance of the two objects was 34′. 22″,58; from thence it was known, how many inches and parts of an inch were anſwerable to that angle. Theſe experiments were repeated every fair day (for no other was ſuitable for theſe obſervations) till we could many times going find the diameter of a body to a ſecond of a degree. From theſe obſervations we were enabled to make a table for the micrometer, as far as the ſcale extended. Theſe experiments were carried yet farther; for, by looking at two bodies whoſe diſtance from each other was known, we could tell their diſtance from the place of obſervation, to a critical exactneſs; and this was proved by accurate menſuration. Theſe were certainly very diverting experiments to an inquiſitive mind! The gentlemen who aſſiſted us through theſe experiments, and likewiſe in the reſt of our work, were the Hon. Stephen Hopkins, Eſq; Mr. Moſes Brown, Dr. Jabez Bowen, Joſeph Naſh, Eſq; and Capt. John Burrough."

"THE regulation of our clocks, being of the utmoſt conſequence in this affair, was what next commanded our attention. In this part of the work we endeavoured to arrive at as great a degree of certainty as the nature of the caſe would admit.--- Several workmen were employed in laying a platform, of ſeaſoned pine plank, as ſmooth and level as art could make it: This was ſecured from rain, or other moiſture, that it might not warp when expoſed to the Sun. We examined this platform three times a day (when the weather would admit of it) with a very long level. On the ſouth ſide of the platform, and exactly perpendicalar to it, we erected a ſtile ten feet high; this was likewiſe examined three times a day. We next perforatod

forated a piece of board, into which was fixed the glaſs of a ſcioptric ball, ſo that the center of the glaſs was exactly in the center of the perforation ; this board was ſo cut, and let in at the top of the ſtile, that it turned upon an axis, in ſuch a manner, that the center of the glaſs did not alter its poſition. The Sun's rays were tranſmitted through the lens upon the platform, where they were formed into a bright ſpot, and very diſtinctly defined. From the center of the lens was let fall a perpendicular upon the platform ; from that point, as a center, was drawn a great number of concentric circles, for taking correſpondent ſhades, in order to trace a meridian line ; and, as our wiſhes would have it, the weather proved favourable for this work. When the line was drawn‡, I found, from calculation, it declined 3′ in time, eaſt of the true meridian ; this error aroſe from the increaſe of the Sun's declination, between the times of forenoon and afternoon ſhades ; this ſmall equation of 3′ was allowed for in regulating the clocks."

"As we were willing to have every corroborating circumſtance to prove our work, we made uſe of the method of correſponding altitudes of the Sun, forenoon and afternoon. The ſextant and reflecter were both employed in this buſineſs for ſeveral days preceeding the tranſit (and the day following) in order to aſcertain the going of the clocks. In the laſt method (as in that of correſponding ſhades) the equation of time, anſwerable to the increaſe of declination, ought by no means to be neglected. The whole proceſs was conducted with the utmoſt caution, that no errors might eſcape our notice. We found upon the whole, a ſurprizing agreement in theſe two methods of regulating clocks ; they were ſeldom found to differ a ſingle ſecond."

"Being in this readineſs, the morning of the third of June was uſhered in with that ſerenity the buſineſs of the day required ; all was calm, and not a cloud to be ſeen. The gentlemen concerned in the buſineſs convened very early at the place

‡ The magnetic needle, being placed on his exact meridian line, was found to differ from it 6° ½ weſtward.

place of obſervation, to ſee that every thing was in order; and at the ſight of ſuch a morning, the gladneſs of their heart was viſibly expreſſed, by the pleaſure of their countenance."

"At noon we examined the going of the clocks, as the Sun paſſed the meridian, and found them very regular."

"We began to look for the firſt contact of Venus with the Sun, at leaſt 15 minutes before the time given by calculation, to get as early a ſight of it as poſſible. Venus was firſt perceived, by making a dent upon the ſuperior limb of the Sun, at 2h. 29′. 43″. P. M. apparent time. But, as it is likely the exterior contacts will be given different, by different obſervers, they can be of but little conſequence in this affair. The greateſt attention was given to the interior contact; this was at 2h. 46′. 35″. apparent time‖. From a mean of a number of good obſervations, the apparent diameter of the Sun was 31′. 40″.66, and that of Venus 58″66; though I could not make it myſelf more than 58″, which was the ſame we found it about a fortnight before the tranſit. The proportion of their diameters was nearly as 1 to 33. The neareſt approach of their centers, at the middle of the tranſit, was taken with the micrometer, and found to be 10′. 5″."

"The proportion of the diſtances of the Sun and Venus from the earth, at that time, was as 3,5143 to 1; then (allowing the Sun's parallax at his mean diſtance to be 8″,68 the ſame

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‖ At the moment of interior contact, the Sun's altitude was taken, with the ſextant, by Mr. Moſes Brown, and by the ſtile by Capt. John Burrough; and both gave the time with the clocks within two ſeconds The total ingreſs was not ſo inſtantaneous as I did expect it would be, but the bright cuſps of the Sun, as they incompaſſed Venus. were much more obtuſe, and there ſeemed to be a faint junction of their limbs for at leaſt 4 ſeconds; the moment this penumbral ligament broke, I proclaimed the time; at firſt I ſuſpected the teleſcope was not adjuſted to a proper focus; but afterwards, by looking at the ſolar ſpots, &c. I was convinced of the contrary. During the time we ſaw Venus upon the Sun, ſhe appeared to be ſurrounded by a ring of a yellowiſh colour; its width was about one tenth of the diameter of Venus. We ſaw nothing that might be taken for a ſatellite.

it was found the 6th of June, 1761) the parallax of Venus was 30′,04; the difference of their parallaxes 21′,49 is the parallax of Venus from the Sun. The angle between the viſible way of Venus and the ecliptic, 8°. 34′. 17′; and the angle made by the axis of the ecliptic and equator, 7°. 3′ 7″; their ſum, 15°. 37′ 24′, was the angle between the axis of the viſible way of Venus, and the Earth's axis. The tranſit line, from total ingreſs to the middle of the tranſit (meaſured in time by the viſible motion of Venus) was 2h. 55′. 36″; but Venus was more accelerated in her orbit (by parallax in longitude) at the middle of the tranſit, than at total ingreſs; this difference of acceleration was 1′. 33″; therefore from the total ingreſs to the middle of the tranſit was 2h. 54′. 3″."

Thence I conclude, that the

* Firſt contact was at - - - -	2h. 28′. 0″	app. time.
But ſeen by us, as above, at -	2. 29. 43	
Interior contact, - - - - -	2. 46. 35	
Middle of the tranſit, - - -	5 40. 38	

" Venus's parallax in longitude, at the middle of the tranſit, was 18″,7; this was paſſed over by Venus's viſible motion in 4′. 44″; ſo that the middle of the tranſit, as ſeen from the center of the earth, was at 5h. 43′. 6″ mean time. The true conjunction was 23′. 21″ before the middle of the tranſit, as ſeen from the earth's center; conſequently the true conjunction was at 5h. 19′. 45″, mean time. At which time, the place of the Sun and Planet was *Gemini* 13°. 27′. 3″; and the geocentric latitude of Venus 10′. 19″,8 north. But her heliocentric latitude was 4′. 6″,51; and by the rules of ſpherical trigonometry, the aſcending node of Venus was 1°. 9′. 23″,5 in conſequence of the Sun, or in *Gemini* 14°. 36′. 26″,5."

" From the foregoing calculation it appears, that the mean motion of Venus is 37″ forward of what it ſtands in Dr. Halley's tables, and her aſcending node 2′. 41″."

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* When I calculated this tranſit, I ſuppoſed the longitude of our place to be much leſs than we have ſince found it by obſervation. by correcting that error, the error in calculation will appear to be inconſiderable.

"It is probable Dr. Halley's ſolar numbers need ſome correction likewiſe; the following may not be far from truth, viz. add to Dr. Halley's mean motion of the Sun, for any year of the Chriſtian æra, 25″, and to the apogee 6′. 18″; for each century after 1700 add 14″,666 to the mean motion, and to the apogee 3′ 53″; then by making uſe of the Pariſian¶ equation of the Sun's center, his place may be had within a ſmall matter of truth."

"By taking the mean of a number of obſervations, the latitude of our obſervatory was found to be 41°. 50′. 41″ north§. The longitude was obtained by obſerving the emerſions of Jupiter's ſatellites, compared with the correſponding obſervations made at Cambridge, in New-England, by Mr. Winthrop, which he was ſo kind as to favour us with; and for which we return him our ſincere thanks Providence was found to be 16′ in longitude weſt from Cambridge. Mr. Winthrop has hitherto found the longitude of Cambridge to be 71°. weſt from the Royal Obſervatory at Greenwich; ſo that the longitude of Providence is about 71° 16′ from the Royal Obſervatory."

"I shall now give the reader a ſhort account of the parallax herein mentioned, and how the planets are affected thereby."

"The horizontal parallax of the Sun is that angle at the Sun's center, which is included between two lines ſuppoſed to be drawn, one from the Sun's center to the center of the earth, the other from the Sun's center to the ſurface of the earth. Or,

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¶ According to the Pariſian hypotheſis, the eccentrity of the earth's orb is 1680 parts, of which the mean diſtance of the earth from the Sun is 100,000.

§ The latitude of the place being of great conſequence, and the ſextant and ſtile not giving it exactly alike, the perſevering Mr Brown contrived to make uſe of the micrometer as a lens, which he placed on his houſe, twenty ſeven feet high, and exactly perpendicular to a center on a horizontal platform below, on which was drawn a meridian line; the Sun's image on this platform was ſeen to move very ſenſibly. By this the latitude was finally determined. The Sun's meridian altitude, being taken for ſeveral days by this long ſtile, the latitudes thence found did not differ from each other more than 15 ſeconds. At the time this was done, we had ſeen no account that a glaſs had been made uſe of, as here deſcribed; but ſince this went to the preſs, we learn from Dr. Long's aſtronomy, that he found the latitude of Cambridge, in England, by the ſame method.

in other words, it is the angle, under which the ſemidiameter of the earth would appear to an eye, at the center of the Sun, The way that parallax affects the Sun and Planets is, it makes them appear below their true places in the heavens, except they be in the zenith of the obſerver; in that caſe parallax hath no effect at all; and the reaſon is, becauſe the obſerver is in that right line which joins the centers of the earth and planet. Parallax may affect the planets places ſeveral ways; as if the obſerver ſhould view the planet upon a vertical, cutting the ecliptic at right angles; in this caſe, parallax will affect its place in reſpect to latitude only; but if the obſerver be ſituated in the plane of the ecliptic, it will then alter its place, in reſpect to longitude only; and if the planet be viewed in an oblique poſition, with reſpect to the ecliptic, parallax will affect its place both in longitude and latitude. The horizontal parallaxes of the planets are to each other in a reciprocal proportion to their diſtances; that is, the planets which are neareſt have the greateſt parallax, and thoſe which are moſt remote, the leaſt. Thence it follows, if two planets are viewed together, that which is neareſt will appear juſt ſo much below the other, as what the difference of their parallaxes is. The nearer a planet is to the horizon of the obſerver, the greater is its parallax, and in the horizon it is the greateſt poſſible; and is then called the horizontal parallax."

"HENCE comes the method of inveſtigating the Sun's parallax, from obſervations of Venus on his diſc. At the time of the tranſit, the third day of June, Venus was much nearer to the earth than the Sun was, and, of conſequence, was much more affected by parallax. This effect was produced in a two-fold manner, in reſpect to us in the northern regions of our earth. Firſt, Venus was depreſſed upon the Sun, by parallax in longitude, bringing her to a conjuction with the Sun ſooner to our point of view, than to a ſpectator at the center of the earth. In the ſecond place, ſhe was carried nearer to the center of the Sun, by parallax in latitude, thereby lengthening the tranſit-line; both which effects conſpired to accelerate the time of firſt interior contact. Now to an obſerver in Great-Britain, parallax had a ſtill greater effect, by what is ſaid before: That is, ſome minutes paſſed after the contact was formed to the

obſerver

observer there, before it was seen by us. Now the difference of longitude, between the two places of observation, being accurately known, the effect of parallax, between the two places, is likewise known; for the difference of longitude, by these observations, will be considerably less than the true difference."

"THE method of calculating the Suns' parallax, from these observations, is by trial; the parallax will be supposed of that quantity, which the observations found it in 1 61; hence the total effect of parallax, at each place of observation, must be computed; and if it should be the same as given by observation, it will prove the assumption to be just; but if, by observation, it should be greater or less than by calculation, the Sun's parallax will turn out to be greater or less in the same proportion.--When the Sun's parallax is known, the distance of the earth, and of all the planets, from the Sun, will be known likewise."

OBSERVATIONS *of the* TRANSIT OF VENUS *over the* SUN, *and the* ECLIPSE *o the* UN, *on* June 3d, 1769. *Made at the* ROYAL OBSERVATORY, GREENWICH. *By the Revd.* NEVIL MASKELYNE, *B. D. F. R. S. and* Astronomer Royal.

Communicated to the Society, By Dr. SMITH, *and ordered to be published, at a Meeting, May 18th,* 1770.

THE weather, which had been cloudy or rainy here, with a south wind, for the greatest part of the day, began to clear up at 4 o'clock in the afternoon, the wind having returned to the west, the same quarter in which it had been the afternoon before, which was remarkably fine and serene, though it changed early in the morning preceding the transit. Towards the approach of Venus's ingress on the Sun, the sky was become again very serene, and so continued all the evening, which afforded as favourable an observation of the transit here as could well be expected, considering that the Sun was only 7°. 3′ high at the external, and 4°. 33 at the internal contact. I observed the external contact of Venus at 7^h. 10′. 58″ apparent time, with an uncertainty seemingly not exceeding